Driver Performance and IVHS Collision Avoidance Systems: A Search for Design-Relevant Measurement Protocols

Robert M. Clarke, Michael J. Goodman. Michael Perel, and Ronald R. Knipling
Office of Crash Avoidance Research
National Highway Traffic Safety Administration

ABSTRACT

Success in developing IVHS collision avoidance systems that are both commercially attractive and effective will depend in large part on how well product designers understand and accommodate human factors considerations in their designs. Help from the human factors community will be sought in this regard and new research will likely be needed to provide designers this information. A review of prior human factors research that may bear on this subject indicates that, in numerous cases, studies were narrowly focused and, as a result, it is sometimes difficult to generalize or extrapolate study findings. This paper suggests that a new set of research tools would be useful to support the identification of design-relevant variables and measures appropriate to the particular issues being studied. Identification of these variables and measures and their validation will help foster the transferability and generalizability of research conducted by different researchers in different research settings. The paper offers a "first-cut" attempt at identifying those variables and measurement approaches, and briefly describes the National Highway Traffic Safety Administration's (NHTSA) programs designed to provide tools that can be used to collect design relevant data. The authors welcome, indeed solicit, comments on the notion of achieving greater uniformity among highway safety researchers in what we measure and how we measure it.

INTRODUCTION

As part of the process of designing, testing and, deploying vehicle-based IVHS collision avoidance systems, there has been a growing awareness of the need to take into account human factors. The focus of this attention is primarily on ensuring that these systems function as intended and are safe when used by the wide array of drivers in the driving population, under a wide range of driving conditions. When searching research results for information relative to driver/vehicle interaction in the context of assessing crash avoidance performance, it is apparent that researchers frequently measure different variables and use different methodological approaches when studying the same issue. As a result, incomparable sets of data are generated that make it difficult to use findings from one study and apply them in andther. This situation is of concern, since with heightened interest in IVHS technologies, it is likely that there will be a significant increase in human factors research to support systems design and evaluate effectiveness. The expected increase in the number of researchers doing work in this area highlights the importance of achieving some level of uniformity in what we measure and how we measure it so that a coherent "body of knowledge" is developed on this subject.

Chapanis (1992), Meister and Enderwick (1992), and others have suggested that to be relevant, human factors research must have as its purpose the development of specific system design recommendations. The authors agree with that premise and suggest that the results of highway safety-human factors research will be better able to develop such recommendations where measured variables and quantifiable metrics of driver performance can be directly or indirectly related to safety--that is, they must have relevance and validity. The development of appropriate tools that can be used to identify and validate the variables and measures appropriate to a given problem area will, we believe, greatly facilitate this process.

NHTSA's human factors research program is attempting to systematically implement an approach that would establish a consistent measurement philosophy supported by the development of a variety of research "tools." These tools will serve to establish uniformity within our own research program, allowing for the collection of standardized sets of measures and interpretive strategies. It is hoped that making these tools available to the highway safety research community in general will facilitate the transferability and generalizability of one set of research findings to another and result in the development of a generally accepted "body of knowledge" to support IVHS systems design and evaluation. These programs are broadly outlined below, along with a framework within which WI-IS research can be implemented.

BACKGROUND

Historically, human factors studies related to the driving task have generally been focused in two broad areas:

- <u>Driver behavior/performance and safety</u>. For example, drivers' ability to perceive and respond appropriately to imminent crash threats, and;

- <u>Optimization of driver/vehicle interfaces</u>. For example, controls and displays, comfort, useability, ride quality, and general questions of ergonomics and consumer preference.

More recently, investigations have focused on the effectiveness of proposed on-board IVHS systems such as traffic and travel information systems and on-board vehicle warning and control systems. The studies that focus on various aspects of the driving task typically exhibit an underlying appreciation of the interrelated effects of driver, vehicle, and environmental factors on overall system performance. This is evidenced by the fact that most studies of this type attempt to control, describe, or measure various aspects of each of these sets of factors. A simple and well-known conceptual model of the interrelationships among these variables is shown in Figure 1.

A more detailed variation on this scheme, and one that bears consideration as a framework within which to develop research measurement approaches, is the classic closed-loop-feedback model which depicts the interaction among driver/vehicle/environment factors, as illustrated in Figure 2.

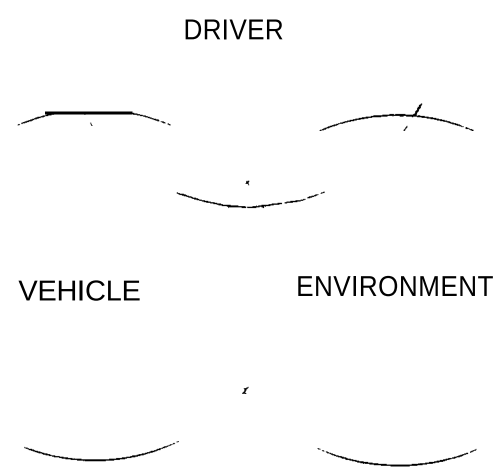

Figure 1. Interaction Among Driver, Vehicle, and Environmental Factors

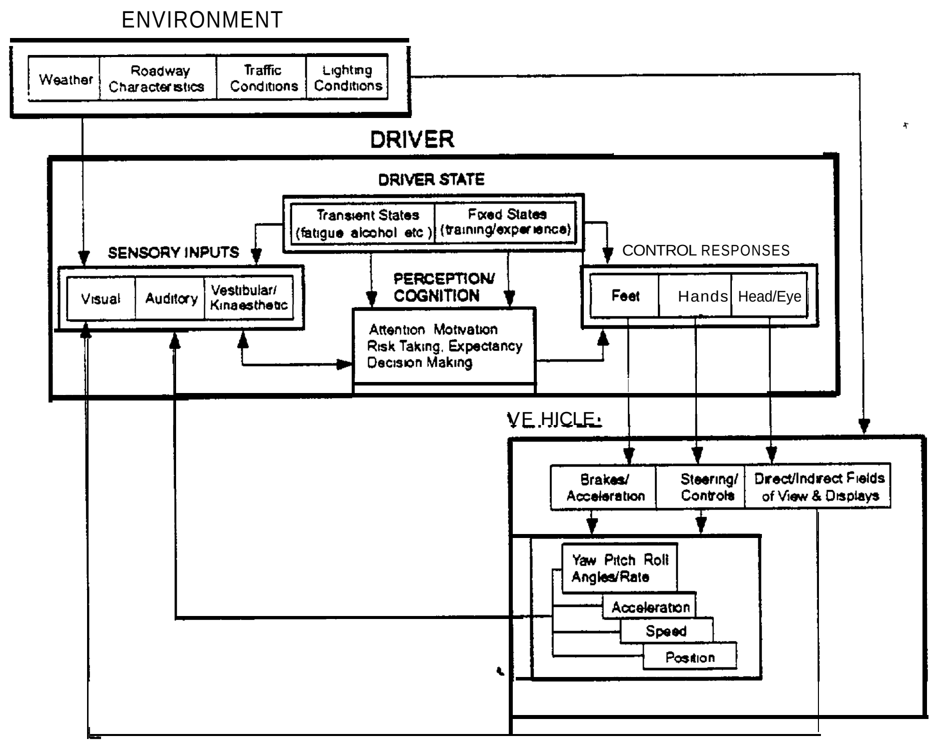

Figure 2. Closed-Loop Feedback Model of Driver/Vehicle/Environment Interaction

DESIGN-RELEVANT PERFORMANCE MEASURES

Within the context of these models, it should be possible to identify a set of variables (driver, vehicle and environmental) and associated measures that can be used when evaluating the performance of different IVHS systems. The challenge for researchers is to identify the set or sets of variables and measures that are relevant. Only in doing so can we determine the true underlying cause and effect relationships among those factors influencing system and driver performance.

Since all these categories of variables can and do influence overall driver/vehicle performance, failing to consider their interrelated effects, or at least attempting to control for them, could, and often does, limit the usefulness of many driving performance-related human factors studies. Additionally, even in cases where descriptions of variables and measures are provided, it is often difficult to generalize and extrapolate findings for identical issues, because different experimental settings and/or driving tasks or scenarios are employed: different parameters are measured using a variety of measurement approaches and indices, or different data analysis and interpretive methodologies are used. These situations point to the desirability of having some degree of uniformity or consensus agreement regarding a number of questions, including:

- Can agreement be reached on the variables that should be measured for a given problem or issue?

- Are there generally agreed upon ways to measure these variables?

- What instrumentation and methodological approaches are available to measure these variables? Which work best, under which situations?

- Are standard data analysis and presentation approaches possible‘?

- What consensus exists relative to interpreting the significance of changes in a measure of a given variable? What magnitude or frequency change must occur for a change to be considered meaningful? For example, for a given variable, is a 5 percent change, even if it is statistically significant, indicative of a meaningful difference or is a change of 50 percent or more needed?

- Can the various experimental settings in which studies are conducted be characterized in a uniform way to enable direct comparisons of the results of different studies?

Answering these questions completely will be difficult and is clearly beyond the scope of this paper. Nevertheless, the authors believe that efforts to address them are necessary if we are to establish a useful “body of knowledge” in this area. While the forum or strategy required to accomplish this is elusive, the NHTSA, through its programs of research and development, hopes to at least begin the process by providing a framework and several necessary tools.

Using the driver/vehicle/environment taxonomy as a framework, an initial “strawman” list of appropriate design relevant variables and measures has been identified for consideration and discussion. It is recognized that not all aspects of these variables (e.g., all six degrees of freedom of motion) need to be measured in a given study. Nevertheless, we suggest that measurements or descriptions of some aspect(s) of each of these variables would enhance the generalizability of research findings. The authors welcome comments on this approach and the list. Following this listing, the specific tools under development to support NHTSA’s IVHS human factors research programs are described.

Environmental Variables

Over the years, testing and evaluation of driver and vehicle performance has been conducted in a wide range of testing environments. The selection of environments available to researchers is growing with the advent of new and more sophisticated and less expensive computing and simulation capabilities. These choices, in approximate ascending order of correspondence to real world driving situations include:

- Laboratory settings with no simulation of highway environment variables
- Fixed-base simulators with highway environment visual scenes with varying levels of sophistication and fidelity
- Controlled test tracks with simulated “real-world” environments of varying levels of fidelity
- Full motion and visual scene simulators with varying levels of fidelity
- In-situ, real world testing and evaluation

How does one choose among these options when studying driver performance and/or behaviors in situations that precede crashes or when studying how drivers perform or behave while taking evasive action? Is one testing environment more appropriate than another? Are some testing environments clearly inappropriate or inadequate for crash avoidance studies, since they are not likely to evoke true driver crash avoidance behaviors or performance‘? Frequently, it is not clear whether researchers studying crash avoidance issues focus on these questions or consider whether their test data will be valid and relevant to real-world crashes. Rather, it appears that the choice of experimental settings is often made on the basis of pragmatic cost and availability considerations, in addition to the basic penchant of the researcher(s) in this regard.

Clearly, the appropriateness of any one of these experimental settings is a function of the particular issue being addressed. For example, studies involving driver preferences, basic ergonomics, or collection of qualitative data often have as their purpose the differentiation of trends or directional tendencies of one variable compared to another. These type of studies often can be conducted satisfactorily in lower-fidelity experimental settings. On the other hand. when studying complex interactions among driver/vehicle/environment factors in crash avoidance contexts, it would appear that there is a need for greater realism and fidelity for the true relationships between the variables of interest to become apparent, (e.g., studies of drivers' responses when confronted with potential crash threats).

Thus, it may be necessary to conduct these type studies in on-road settings, in order to accurately determine and quantitatively measure drivers' performance or behaviors in situations that are hypothesized to precipitate conflicts or crashes. Ultimately, however, as the risks inherent in these situations increase, a dilemma is created. If the risks become high, the evaluation simply cannot be performed in a real world environment for test subject safety reasons. On the other hand, reducing the character of the test conditions to eliminate these concerns likely elicits different driver behaviors and levels of performance than would have occurred in the "real" situation, thereby compromising or completely invalidating findings made under these "compromised" conditions. Is there a solution to this problem?

The answer may lie in advanced technology, high fidelity, full motion simulators such as the National Advanced Driving Simulator (NADS). In this kind of experimental setting, drivers can safely be exposed to highly realistic, imminent crash threat situations. Research that has never been attempted and which may ultimately yield answers about what drivers actually do in crash-threatening situations, will be possible when this experimental tool becomes available. Studies performed with this tool will help establish the usefulness of studies using lower fidelity experimental settings. Until these studies are carried out, it will not be possible to know, with any degree of certainty, whether driver performance and behavior in these lower fidelity settings are representative of what actually occurs in real-world driving situations.

Highway/Environment Measures

Until the NADS becomes available, whatever the choice of experimental setting, a set of variables describing the environmental conditions should be identified, used, and reported by researchers. The authors suggest that the following list of variables directly or inferentially describes the risk and opportunities for conflict inherent in any driving scenario that a subject test driver would likely be asked to negotiate. It is further suggested that uniform narrative definitions and descriptions for these variables be established, agreed upon, and used. The definitions and descriptions used in NHTSA's Fatal Accident Reporting System (FARS) are a reasonable starting point for this effort.

Use of these narrative descriptions will suffice in most studies in which environmental variables are controlled or fixed and are not an issue in the study. In other studies in which environmental issues are a focus of concern, more precise descriptions of these variables will be needed. Physical measurements of these variables would be appropriate in these situations and are suggested below. It may be useful as well, especially for experiments involving long time duration driving scenarios, to have available an algorithm which integrates the "magnitude" of each of these variables into a single time-variant ordinal metric of risk or stressfulness inherent in the test scenario being used in the experiment. Comments are especially welcomed on the potential utility of such a metric. Environmental variables of interest include:

- Weather - clear, raining, snowing, etc. (or more direct indicants of atmospheric visibility conditions and, in cases where it is relevant, ambient wind velocity and direction relative to vehicle direction of travel)

- Lighting Conditions - daylight, dawn, dusk, night, unlit highway, illuminated highway (or, again, more direct indicants of ambient light levels)

- Travel Lanes - number in each direction of travel (as an inferential indicant of conflict opportunity)

- Road Geometry - primarily road curvature and inclination (or more direct indicants of roadway radius of curvature and percent grade)

- Traffic Flow - divided or undivided (another inferential indicant of conflict opportunity).

- Surface Conditions - dry, wet, snow, ice (or a more direct indicant of surface coefficient of friction)

- At-Grade Intersections or Junctions Per Mile of Travel - either signalized or signed (another inferential indicant of conflict opportunity)

- Prevailing Speed of Traffic - average speed of vehicles in the traffic stream

- Traffic Density - a measure of the “tightness” or closeness of other vehicles travelling in relative proximity to the test vehicle. This could either be measured directly or implied as some function of the ratio of current Average Traffic Density (ATD) to peak ATD.

Driver Variables

As suggested by the Figure 2, driver/vehicle/environment interaction model, it would be desirable to collect four categories of measures relevant to the driver: the condition or status of the driver, sensory inputs, perceptual/cognitive activity, and physical responses/controlling actions. Measurement of some of these variables is straightforward, while others represent a particular challenge.

The condition or status of a driver may be either fixed or variable depending upon the intent of the researcher. For example, the state in which an individual enters a study, such as experience, level of training, blood alcohol level, etc., are typically fixed as control variables and do not have to be continuously measured. In other cases, the condition or status of the driver may be manipulated by the researcher, as for example, with driving time and fatigue.

Intervening between sensory inputs and control responses, perceptual/cognitive activities can only be inferred indirectly through surrogate measures. Among the most frequently used are subjective assessments and/or questionnaires. Secondary tasks are another approach that is sometimes used to “get at” cognitive processes, but this experimental technique often lacks direct relevance to driving, thereby making interpretation/application of results problematic.

A notable exception, however, is secondary tasks associated with use of in-vehicle IVHS systems where perceptual and cognitive demands on the driver represent a significant component of overall vehicle operation. In these instances, defining appropriate measures of perceptual/cognitive activity is critical in determining not only the effectiveness of the systems, but also the safety implications of their use.

The following are offered as a candidate list of measures of driver performance, activity, cognitive processes, and psychophysiological state. Note that measures of driver input to vehicle controls will be made under the category of vehicle response measures.

<u>Sensory Input Measures</u>

Visual. This is the key sensory input drivers use in executing the driving task. It therefore seems appropriate that a measure of visual input be developed for use in studies of driver performance. The most widely employed measurement scheme (if any measurement of this variable is attempted at all) appears to be video recording, usually followed by manual post-processing of the images and screening for head/eye movements, glance frequency, glace duration, etc. Other approaches could employ a 3-axis position sensor that is worn on the head of a test subject, or the use of cornea1 reflection measurements. Typically, measures from these approaches are correlated with the presence of objects (e.g., mirrors) known to be in the zones of visual attention. Indices of glance frequency and duration are usually derived, or time interrelationships determined between head/eye movements/point-of-regard and other simultaneously occurring variables (e.g., the presence of a “threat,” the activation of a display, etc.) in the experiment. The authors welcome input from researchers about the practicality, reliability, etc., of these and any other methodologies that have been employed to obtain these type of measurements. Comments would also be welcomed about how to reduce and report this type of data in a standardized manner.

Auditory. The need to continuously record this variable may be relevant only if auditory signalling (either internal or external to the vehicle), radio use, or voice communicating are experimental issues. If not, it may only be necessary to ensure appropriate background noise(s) for the environmental scenario being used in the study.

Vestibular/Kinesthetic. It should be possible to infer these measures from vehicle-based measurements of vehicle translational/angular motion. Some studies might warrant on-body or on-seat measurements of these variables if vehicle-to-seat-to-driver damping is an issue.

<u>Cognitive Process Measures</u>

In addition to inferring the nature of cognitive processes from psychophysiological or direct driving performance measures, subjective assessments or verbal descriptions of what test subjects felt was happening when they were undergoing testing may be the best way to "measure" this aspect of human performance. Opinions are wide ranging (Muckler [1992] and Hill, et al. [1992]) as to the efficacy of this methodological approach, but regardless, it remains a tool that cannot be overlooked. No standardized approach to collecting subjective assessments is readily apparent. However, open-ended discussions are an effective method of eliciting candid, non-biased opinions.

Psychophysiological Status Measures

A large number and wide variety of measures designed to gauge driver psychophysiological status have been suggested and used in past driving performance related studies, most often in ones related to long driving time/fatigue. This list includes: electrocardiograms (EKG), electroencephalograms (EEG), electromyograms (EMG), galvanic skin resistance (GSR), respiration rate, body temperature, eye blink frequency/pattern of eye movements, urinary metabolite and electrolyte levels, blood pressure, blood epinephrine and norepinephrine levels, and whole body and/or individual limb(s) position/movement sensing. Opinions vary widely about the interpretation and, therefore, the usefulness of many of these measures.

However, heart rate and its derivatives appear to be the one measure that is used more consistently than others in this context, in addition to the obvious measure of full eye closures, which can be derived from the vision measurement methodology described above. Therefore heart rate is suggested here as an additional measure that could be collected routinely in experimental situations where driver psychophysiological state is relevant to the issue being studied. Comment is sought on the sensitivity, validity, and interpretation of this measure.

Vehicle Performance Variables

Information about three distinct sets of variables are needed: those indicating control inputs the driver makes to the vehicle; those indicating the results of those control inputs in terms of the dynamic response characteristics of the vehicle, and the vehicle's juxtaposition relative to the roadway and other vehicles in its vicinity.

Driver Control Input Measures

These are straightforward and include as a function of time:

- Steering wheel angular position and its derivatives
- Brake pedal activation and brake pressure
- Accelerator/throttle position and its derivatives
- Auxiliary control activation/settings (e.g., wipers, lights, IVHS devices, etc.)

Vehicle Dynamics Response Measures

These also are straightforward and include as a function of time:

- Vehicle motion as measured by the vehicle's center of mass lateral, longitudinal, vertical, pitch, roll, and yaw positions/velocities/accelerations. All these measures may not be necessary in every study, nevertheless, some measure(s) of vehicle motion appears essential.

Vehicle Juxtaposition Measures

Obtaining these measures will be difficult, but the value of the information should be high. Ideally, one would like to know the relative position of the vehicle within its lane of travel, as well as the relative motions of other vehicles in the vicinity of the test subject's vehicle. Hence, the measures would be:

- Headway

- Vehicle lateral position relative to lane edge

- Vehicle center of mass lateral, longitudinal, vertical, pitch, roll, and yaw positions/velocities/accelerations, for vehicles in the immediate vicinity of, or adjacent to, the subject vehicle. It is recognized that the means to gather these data does not currently exist. Nevertheless, development of this type of measurement capability would greatly improve understanding of the reasons why test drivers behave/perform the way they do.

Summary List of Suggested Variables and Measures

Table 1 summarizes the authors' suggestions for a set of design-relevant variables and their associated measures that are appropriate for studies of driver performance and IVHS collision-avoidance systems.

NHTSA PROGRAMS

NHTSA is in the process a developing a number of tools to enhance our ability to study human factors issues related to the design, development, and use of IVHS collision avoidance systems. These tools include: an advanced state of the art research driving simulator; portable instrumentation and data acquisitions systems for installation on production vehicles that will be built in multiple numbers and used in on-road studies; and a vehicle motion environment system that will be fixed at highway sites to gather data describing both normal, and potentially crash-producing, inter-vehicle trajectories and motions.

The availability of these tools creates the potential for altering the approaches human factors researchers take in formulating and designing studies directed at driver/hardware system interaction and human performance issues related to the use of vehicle-based, and specifically IVHS collision avoidance, hardware systems. Use of these tools will significantly increase the types and number of measures that can be collected compared to what is now possible.

TABLE 1 List of Suggested Variables and Measures

Variables	Measure
Highway/Environment	
Weather Condition	Unresmcted sight distance due to atmospheric conditions (meters): wind velocity (m/s) and direction. If this and the other highwayienvironment variables are not directly measured, it should be characterized in terms of the applicable FARS data element listing.
Lighting Conditions	Ambient light levels (ft. lamberts)
Road geometry	Roadway radius of curvature and percent grade
Surface Condition	Road surface coefficient of friction
Travel Speed	Average speed of vehicles in the traffic stream
Traffic Density	Direct measures of inter-vehicle relative positions, or more simply. current Average Traffic Density (# veh/hr./lane)
Driver	
Vision	Eye pomt of regard/eye closure, referenced in polar coordinates from the normal seated eye position and further referenced to fixed positions of objects/devices within/on the vehicle or objects in the traffic environment
Alertness Wakefulness	Heart Rate (HR) and its derivative indices (probably only appropriate/needed in fatigue related studies)
Cognitiv e Processes	Subjective Self Reports. no standard approach is apparent
Vehicle	
Steering	Steering wheel angle, rotational velocity and acceleration
Braking	Brake pedal pressure time history
Accelerating Speed Controlling	Accelerator pedal position. velocity, and acceleration
Auxiliary Control Activations	Position/setting switches for radios, wipers, lights. etc. (as appropriate)
Vehicle Dynamics Status	Three-axis linear and rotational position of the vehicle's center of mass (derivatives can be obtained as needed). All measures may not need to be taken in every case.
Inter-Vehicle Positional Relationships	Three-axis linear and rotational position of vehicles in the immediate vicinity of, or adjacent to, the subject vehicle. Until this capability becomes available. critical aspects of the actions/motions of ether vehicles (e.g.. braking onset. headway, etc.) in the vicinity of the test vehicle should be defined as precisely as possible.

All these tools have in common an ability to generate empirical data describing various aspects of driver, vehicle, and highway/environment activities and performance in a wide variety of contexts. The agency views this as an opportunity to expand both the quantity and quality of human factors research performed in this area. While a detailed description of these programs is beyond the scope of this paper, brief descriptions are offered to illustrate the direction of our program as well as our commitment to improving the availability of tools to human factors highway safety research community.

Measurement Tools

The National Advanced Driving Simulator (NADS)

In a cooperative public/private sector effort, the NHTSA is developing the NADS facility (Figure 3.) which will, for the first time, allow studies of driver performance under imminent crash threat situations where subject safety and realism are both important. The simulator will have the capability of collecting all the measures described above as well as additional ones that may only occasionally be used for highly focused studies, e.g., cab temperature measurements will be possible for situations in which a measure of this variable may be important. A number of standardized driving scenes or scenarios that represent the majority of driving situations in which crashes occur will be available for use by researchers. Within a given scenario, full control and measurement of environmental variables (e.g. day/night, dry/wet, etc.) will be possible. Continuous measurements of the position, velocity, acceleration, etc., of the test subject's vehicle as well as other vehicles in the driving scene will be possible. It will also be possible to time interrelate measurements of all these variables to each other .

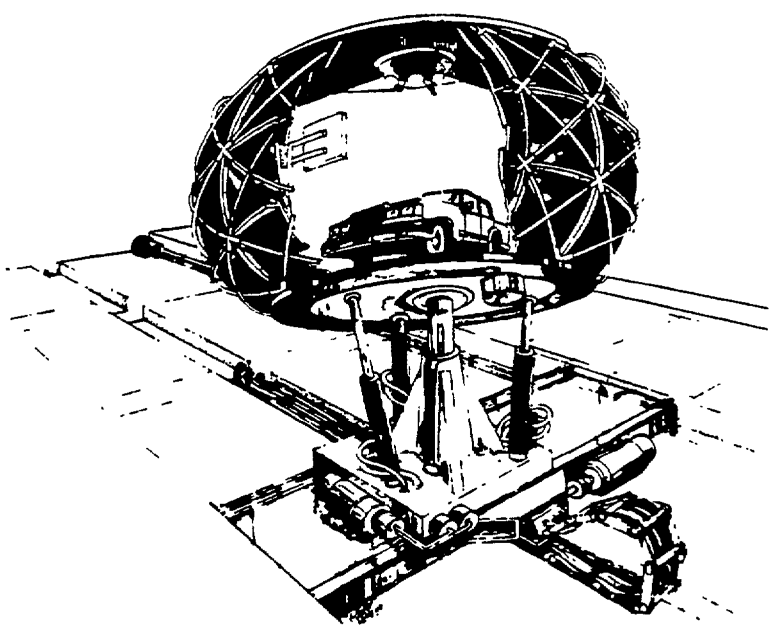

Figure 3. National Advanced Driving Simulator (NADS)

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Driving Simulation Scenario Development

To be useful and valid, driving simulators must be equipped with realistic and relevant driving scenarios--driving environments, events, tasks, and threats that replicate the "real world" of driving. A review of motor vehicle crash data reveals that a comparatively small number of "baseline" roadway types/traffic conditions encompass the vast majority of situations in which motor vehicles travel and in which crashes occur. These include. but are not limited to, roadway settings such as:

- Urban freeway
- Rural interstate
- Rural two-lane arterial
- Urban/suburban minor arterial
- Local street

In addition to being able to generate the basic scenes, a capability for varying parameters within these settings--e.g., speed limit, traffic density, density of intersections, and weather conditions--is also needed. Work is underway within the agency to identify, define, and develop a well defined set of traffic scenarios and their key variable characteristics that could be widely used by researchers, thereby improving the generalizability of results. The goal of this work will be to develop a set of driving simulation scenarios for crash avoidance research that are crash-relevant, practical, and transferable to the NADS, as well as other simulators.

Ultimately, a group of roadway environments will be identified, along with an associated set of "events" within each, that can be varied according to experimenter needs. For example, a simulation experiment on countermeasures for lane change/merge crashes might employ the "standardized urban freeway" setting modified to be rich in merge and lane change events.

Portable Data Acquisition System For Crash Avoidance Research (DASCAR)

A range of portable instrumentation packages (DASCAR) for installation in actual vehicles to use in on-the-road testing are also being developed. These instrumentation packages will permit evaluations in real-world traffic situations.

Development of the DASCAR system(s) will be based on a systematic evaluation of state-of-the-art technologies and the desire to build a relatively inexpensive modular system that can accommodate a wide variety of problems and can be installed in any vehicle within a short period of time. A schematic of the system is shown in Figure 4.

Depending on the type of study being conducted: researchers could select from a "menu" of sensors and processors to collect data relevant to their topic of concern. It is envisioned that, at a minimum, the measures shown in Table 1 will be obtained. Once the DASCAR design is finalized. multiple units will be built and simultaneously used in a variety of studies the agency plans to sponsor.

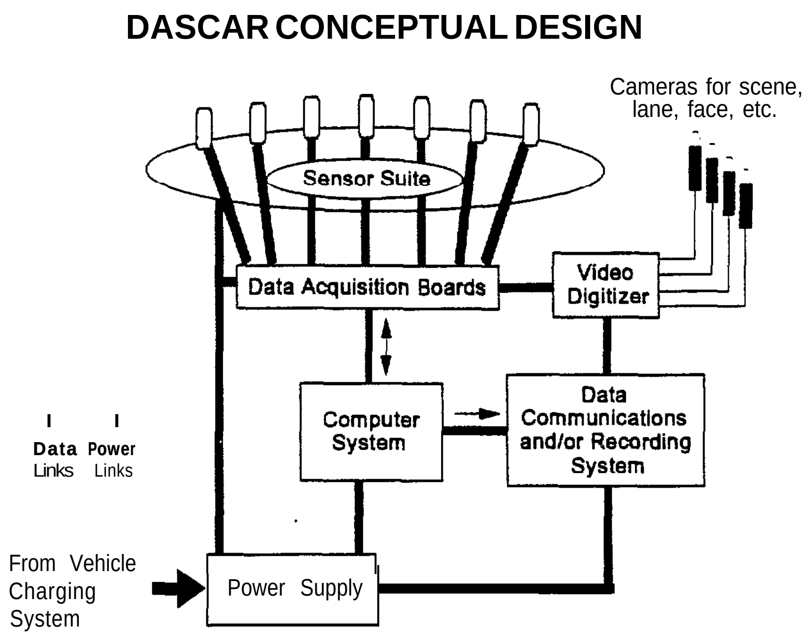

Figure 4. Data Acquisition System for Crash Avoidance Research (DASCAR)

Vehicle Motion Environment Measurement System (VME)

Work has begun to develop a remote measurement system that could be fixed at given highway sites to gather vehicle motion data. A schematic of the system is shown in Figure 5. Inter-vehicle trajectories will be analyzed to develop time-history relationships among merging, slowing, accelerating, and turning vehicles at the site. Results of these analyses will provide statistical information describing exposures to the risk of various types of collisions, described in terms of the vehicle headways, velocities, etc., that tend to precede various types of collisions or near miss collisions. This type of information will assist product designers in developing logic algorithms of various types of IVHS collision avoidance systems.

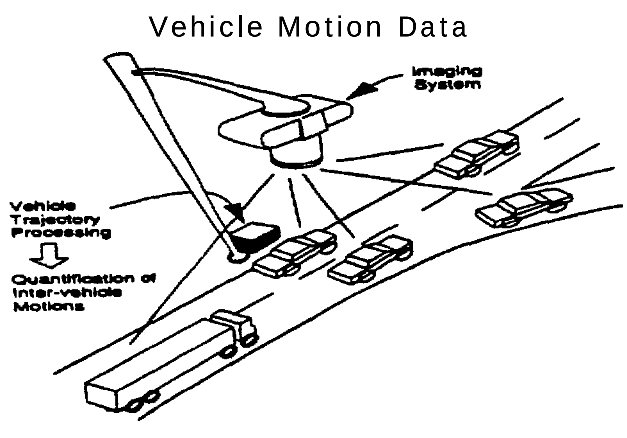

Figure 5. Vehicle Motion Environment Measurement System (VME)

SUMMARY

A great deal of effort is being expended by academia, industry, and government to study and understand detailed aspects of driver/vehicle performance as it relates to motor vehicle crashes in an effort to develop concepts, and eventually detailed designs, for advanced technology IVHS collision avoidance systems. For its part, NHTSA will utilize a systematic approach to evaluating driver/vehicle interaction and driver performance/behavior by identifying a list of appropriate variables, and their associated measures. These measures will gauge aspects of the overall driving task that are directly relevant to design qualities of the devices that are being conceptualized and built. The measures will then be used to support research programs sponsored or performed by the agency. This paper presents an initial list of variables and measures that could be used by NHTSA and others to collectively develop a "body of knowledge" that would be applicable to the design and evaluation of IVHS crash avoidance systems. Specific tools for developing this information base are currently under development by the NHTSA. Discussion is welcomed and sought on the list of variables and measures in the hope that, ultimately, consensus of agreement can be reached among researchers regarding the most design-relevant and useful measurement protocols.

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